Evaluation of Employees' Exposures to Lead, Noise, and Heat at an Automotive Lead-acid Battery Recycling Company

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Contents

The employer is required to post a copy of this report for 30 days at or near the workplace(s) of affected employees. The employer must take steps to ensure that the posted report is not altered, defaced, or covered by other material.

The cover photo is a close-up image of sorbent tubes, which are used by the HHE Program to measure airborne exposures. This photo is an artistic representation that may not be related to this Health Hazard Evaluation. Photo by NIOSH.

Highlights of this Evaluation

The Health Hazard Evaluation Program received a confidential request from employees at an automotive lead-acid battery recycling company in Puerto Rico. Employees were concerned about exposures to lead and noise. We visited the battery recycling company in April 2012 and September 2012.

What We Did

- We interviewed employees about their medical and work history.
- We looked at work practices.
- We sampled for lead in air and on surfaces.
- We looked at the company's records of employee blood lead tests between July 2009 and July 2013.
- We measured employees' noise exposures.
- We measured temperature and humidity in the workplace.
- We looked at the company's health and safety programs.

Employees were overexposed to airborne lead, noise, and heat. We recommend enclosing the battery breaker and shredder, improving ventilation, providing more protective respirators for certain jobs, and following a heat stress prevention work and rest schedule. We also recommend starting hearing conservation and heat stress management programs and improving other health and safety programs.

What We Found

- Foundry, battery breaker, and some warehouse and maintenance employees were overexposed to lead in air.
- Average employee blood lead levels declined from 2009–2013. However, in 2013, 78 percent of employees had an average blood lead level at or above the recommended limit of 10 micrograms per deciliter.
- Eighty-five percent of interviewed employees reported at least one symptom that could be related to lead overexposure.
- We found lead on most work surfaces that we sampled.
- We found lead on employees' skin after they took a shower at the end of the work day.
- Foundry and battery breaker employees were overexposed to noise.
- Heat stress conditions existed throughout the production areas of the plant.
- Local exhaust ventilation was poor or not available.
- Health and safety programs were incomplete or missing.

What the Employer Can Do

- Make a path so that employees can go from the clean locker room to the lunchroom without crossing lead-contaminated areas.
- Install ventilated enclosures around the battery breaker and shredder.
- Separate the battery breaker, lead mixing, and furnace loading areas.
- Provide more local exhaust ventilation while drossing and improve manual drossing procedures to reduce lead exposures.
- Encourage employees to report any health concerns that may be related to their work to their supervisors and health care provider. Establish a formal written procedure for plant staff to follow in how to respond to health and safety concerns.
- Continue blood lead testing of employees. Follow current guidelines.
- Start hearing conservation and heat stress management programs.
- Improve respiratory protection and hazard communication programs.
- Start a health and safety committee that includes managers and employees.

What Employees Can Do

- Wear all required personal protective equipment, including hearing protectors.
- Do not eat or drink in work areas.
- Keep your hands and exposed skin as clean as possible while at work.
- Wash your hands before eating, drinking, and leaving work. Use a lead removal cleaner, not soap and water.
- Do not bring your work clothes or boots home. If you bring underwear or socks home, wash them separately from other clothes.
- Drink plenty of water at work and take rest breaks.
- Participate in the health and safety committee.
- Tell your supervisor if you have any work-related health concerns.
- Contact the Occupational Safety and Health Administration if you are concerned about unsafe working conditions.

Abbreviations

µg/dL	Micrograms per deciliter
µg/m^3	Micrograms per cubic meter
µg/wipe	Micrograms per wipe
ACGIH®	American Conference of Governmental Industrial Hygienists
BLL	Blood lead level
CFR	Code of Federal Regulations
dBA	Decibels, A-scale
GM	Geometric mean
NIOSH	National Institute for Occupational Safety and Health
NTP	National Toxicology Program
OEL	Occupational exposure limit
OSHA	Occupational Safety and Health Administration
PEL	Permissible exposure limit
PPE	Personal protective equipment
REL	Recommended exposure limit
TLV®	Threshold limit value
TWA	Time-weighted average
WBGT	Wet bulb globe temperature

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Introduction

In January 2012, the National Institute for Occupational Safety and Health (NIOSH) received a confidential request for a health hazard evaluation from employees at a battery recycling company in Puerto Rico. The request concerned potential respiratory and dermal exposures to lead, caustic soda, sodium nitrate, recycled oil, and sulfur. Reported health effects included headache, throat irritation, stomach problems, tiredness, body aches, and dizziness. We evaluated the plant in April and September 2012 and sent interim letters with findings and recommendations after each visit. In November 2012 we sent a letter summarizing the air sampling results for lead and noise to the company and employee requestors and in January 2013 we individually notified the employees of their air sampling results for lead and noise. In April 2013 we provided the company with a letter summarizing the results from our heat stress evaluation.

Other federal and local government agencies have evaluated this plant. In 2010, the Puerto Rico Department of Health investigated reports of blood lead levels (BLLs) of ≥ 10 micrograms per deciliter (µg/dL) in children linked to relatives employed at the plant. In 2012, the Puerto Rico Occupational Safety and Health Administration (OSHA) cited the company for violations of health and safety regulations. The U.S. Environmental Protection Agency evaluated lead contamination of employees' homes and personal vehicles and environmental release of lead from the plant. We shared information with these other agencies during our evaluation.

Work Process

The company collected automotive batteries and operated a secondary lead smelter 24 hours a day, 365 days a year. The company processed approximately 55,000 metric tons of used batteries a year (an average of 975,000 batteries a year), producing 27,500 metric tons of secondary lead. The company had 106 employees at the time of our first visit.

The battery recycling process began when employees manually unloaded automotive batteries from pallets and placed them onto a conveyor belt that took them to a shredder (Figure 1). After shredding, the battery material fell into a water bath to separate the lead, lead oxide, battery acid, plastics, and other components. After separation, lead and lead oxide-containing materials were air dried and mixed with coal, soda ash, and scrap metal by employees using front-end loaders (Figure 2). The lead mixture was then transferred to one of two rotating furnaces in the foundry area for melting (Figure 3). Molten lead was transferred to one of five kettles for refining (Figure 4). The refined lead (up to 99.99% pure) was cast into 1-ton nuggets or 50-pound ingots. Employees manually skimmed impurities that floated to the top of the molten lead in a process called drossing (Figure 5). Employees also manually removed excess lead (called flashing) from castings. The dross and flashing were reused in the furnaces.

Figure 1. Two employees unloading batteries onto a conveyor belt. Photo by NIOSH.

Figure 2. Area where lead-containing materials were air dried and then mixed with coal, soda ash, and scrap metal by employees using front-end loaders. Photo by NIOSH.

Figure 3. A front loader moving a mixture of lead-containing materials and soda ash into a furnace. Photo by NIOSH.

Figure 4. Kettle used for refining lead. Photo by NIOSH.

Figure 5. Employee scraping floating impurities (dross) from molten lead nuggets. Photo by NIOSH.

Canopy hoods above the furnaces and kettles exhausted particulate to one of two bag houses where lead particulate collected in a drum. Furnace employees emptied the drum into the furnaces at least once per shift. Wastewater from the plant was treated onsite before discharge.

The company displayed posters in English and Spanish that showed employees how to wear personal protective equipment (PPE). During our April 2012 visit, employees wore hard hats, full facepiece or half-mask respirators equipped with acid gas cartridges and P100 filters, latex gloves, metatarsal safety boots, and employer-provided uniform pants and short-sleeve shirts. Employees working with molten metal were also required to wear a face shield, leather gloves, and a leather jacket over the work uniform. During our September 2012 visit, the company required foundry and battery breaker employees to wear full facepiece respirators equipped with acid gas cartridges and P100 filters. The company provided employees with uniforms and boots, access to showering facilities, and separate lockers for their personal and work clothes.

Methods

We discussed the request with employer and employee representatives. We observed workplace conditions and work processes and practices. Our objectives were to:

1. Evaluate employee exposures to lead, noise, and heat.
2. Identify employee health concerns that could be related to work.
3. Identify methods to reduce lead exposures, noise exposures, and heat stress.

Measurement of Lead, Noise, and Heat Exposures

We took full-shift, time-weighted average (TWA) personal and area air samples for lead. The air samples were analyzed by NIOSH Method 7303, with modification [NIOSH 2014a]. The modification included wiping the interior of the filter cassette with a wet smear tab to collect particles on the inside walls. This practice is consistent with the current NIOSH recommendation that all particles entering the sampler be included as part of the sample whether they deposit on the filter or on the inside surfaces of the sampler [NIOSH 2014a]. We then analyzed the smear tab wipe along with the sample filter [NIOSH 2014a]. We compared personal air sample results for lead to occupational exposure limits (OELs). We analyzed the results using American Industrial Hygiene Association IHSTAT V229 to calculate the distribution, range, central tendencies, geometric standard deviation, and percent of personal samples above an OEL.

We used integrating noise dosimeters to measure TWA personal noise exposure on five employees per day. The dosimeters simultaneously collected data on three different settings to compare noise measurements with the OSHA permissible exposure limit (PEL), the OSHA action level, and the NIOSH recommended exposure limit (REL). We used an integrating sound level meter and real-time frequency analyzer to measure area noise levels and octave band noise levels (i.e., measurement of noise levels across different frequencies).

We measured temperature, relative humidity, and radiant heat in the furnace and kettle areas to calculate the wet bulb globe temperature (WBGT), an index used to assess the potential for developing heat stress. We estimated the metabolic work rate of employees and then compared the WBGT measurements and workload estimates to the NIOSH RELs and American Conference of Governmental Industrial Hygienists (ACGIH) threshold limit values (TLVs) for thermal stress [NIOSH 1986; ACGIH 2014].

Lead on Work Surfaces, Skin, and Clothing

We used SKC Inc. Full Disclosure® wipes to look for lead on surfaces. These wipes had an estimated visual limit of identification of approximately 18 micrograms of lead per wipe (µg/wipe). We then used NIOSH Method 9102 [NIOSH 2014a] to quantify the amount of lead on the wipes and compared these results to our visual estimation to see if they agreed. The limit of detection for lead by NIOSH Method 9102 was 0.2 µg. We used a 10 centimeter by 10 centimeter template to outline the sample area, where possible. For small or irregularly shaped surfaces we estimated 100 square centimeters of sample area or took a sample of the entire area or object. We wore a new pair of gloves to take each sample.

On our first visit, we collected a hand wipe sample on each of six employees after they showered. On our second visit, we collected 14 hand wipe samples from seven employees over 2 days after they showered. For both visits, the employee used one side to wipe the palms and top surfaces of both hands up to and including the wrist and between fingers for about 30 seconds.

We sent eight wipe samples (ESCA Tech, Inc. D-Lead® Test Kit for Lead) collected by the company to our contract laboratory to measure lead. We did this to see if the company's interpretation of the visual color change on the wipes corresponded to a quantitative laboratory analysis for lead.

Employee Interviews

We held voluntary, confidential medical interviews in English and Spanish with employees selected from a company roster on the basis of their job title, length of employment with the company, age, and work shift. Information collected in the interviews included job title, age, length of employment, and work history; medical history; symptoms experienced during work; PPE use; and health and workplace concerns associated with lead toxicity.

Company Health and Safety Policies and Procedures

We met with the company physician and discussed medical policies and procedures including the OSHA-mandated lead program, which included respiratory clearance examinations and periodic BLLs. We obtained the OSHA Form 300 Log of Work-Related Injuries and Illnesses for the years 2010–2012. We evaluated medical records of a plant employee previously evaluated for lead intoxication. We obtained copies of the company's written health and safety programs and looked at the results of previous industrial hygiene monitoring. We also reviewed employee BLL test results from July 2009–July 2013. The company documented BLLs in micrograms per 100 grams, which we converted to µg/dL for comparison to OELs.

Results and Discussion

Air Sampling for Lead

The personal air sample results are summarized in Table 1, and individual personal air sample results are shown in Appendix A, Tables A1–A3. These personal air samples were intended to represent exposures experienced during the employees' full 8-hour workshift. However, sampling pumps were not worn when employees showered and changed uniforms before lunch break and at the end of the shift, and during the lunch break itself. Full-shift area air sampling results are shown in Appendix A, Tables A4–A6. Of the 36 personal samples, 30 exceeded the NIOSH REL and OSHA PEL for lead of 50 micrograms per cubic meter (µg/m^3). The highest personal exposures were measured on foundry employees during furnace loading (up to 4,100 µg/m^3) and drossing (2,700 µg/m^3) (Appendix A, Table A1). Lead exposures at the battery breaker were up to 320 µg/m^3 (Appendix A, Table A3). We measured a short-term (25-minute) lead concentration of 2,700 µg/m^3 on an employee who jackhammered slag from a kettle (data not in tables). Even if this employee received no further lead exposure for the remainder of the workday this exposure still exceeded the NIOSH REL and OSHA PEL for lead.

Warehouse and maintenance employees' exposures to lead were 12–190 µg/m^3 (Appendix A, Tables A1–A3). Although these exposures were lower than those on foundry and battery breaker employees, two of the three personal air samples we took on warehouse employees and three of six personal samples on maintenance workers exceeded the NIOSH REL and OSHA PEL (Table 1). None of the personal exposures on water treatment employees exceeded the OELs, but one exceeded the OSHA action level.

Table 1. Summary of full-shift personal air sample results for lead, September 11–13, 2012

Job title	No. of samples	Concentrations (µg/m^3)	Geometric mean	Geometric standard deviation	% samples above OEL
Foundry	19	93 to 4100	530	2.8	100
Battery breaker	5	180 to 320	230	1.3	100
Warehouse	3	12 to 190	52	4.0	67
Maintenance	6	20 to 80	44	1.8	50
Water treatment	3	4 to 31	13	2.9	0

The company had a written program specifying the types and locations where respirators were required. At the time of our September 2012 visit, all employees under this written respiratory protection program were qualitatively fit-tested annually using Bitrex® and were required to wear either a full facepiece or half-mask elastomeric respirator equipped with a combination organic vapor and acid gas cartridge and P100 filter. The NIOSH assigned protection factor is 10 for a half-mask respirator and 50 for a full facepiece respirator. Multiplying the NIOSH assigned protection factor of 50 (full facepiece respirator) by the occupational exposure limit for lead of 50 µg/m^3 gives a maximum use concentration of 2,500 µg/m^3. Because some measured full-shift personal exposures to airborne lead exceeded this maximum use concentration during furnace loading and drossing, a full facepiece air-purifying respirator would not be sufficiently protective. We notified the company and confidential employee requestors of this finding in a letter dated November 21, 2012.

On the basis of the results from the personal air sampling we conducted for lead, and using NIOSH respiratory selection criteria, employees loading furnaces and drossing kettles should wear a higher level of respiratory protection than observed during the site visit until further controls can be implemented to reduce airborne lead concentrations. According to NIOSH, the next highest level of respiratory protection is a pressure-demand supplied-air respirator with a half-mask or a full facepiece; this respirator has a NIOSH-assigned protection factor of 1,000 [NIOSH 2004]. However, according to the OSHA respirator standard [29 CFR 1910.134], a tight-fitting full facepiece powered air-purifying respirator would be sufficient. This respirator has an OSHA assigned protection factor of 1,000. While these powered air-purifying respirators were not used at the time of the site visit when airborne lead measurements were taken, they are currently required.

Following our November 21, 2012 letter, the company requires employees to wear tight-fitting full facepiece powered air-purifying respirators equipped with a combination organic vapor and acid gas cartridge and P100 filters.

In addition to personal air samples, we took area air samples for lead in production and non-production areas to identify locations where lead concentrations were the highest and where engineering controls may be most useful (Appendix A, Tables A4–A6). We found the highest airborne lead concentrations at the top of the battery breaker (up to 2,500 µg/m^3), in the furnace loading/charge mixing area (up to 640 µg/m^3), and in the battery breaker discharge area (610 µg/m^3) (Appendix A, Tables A5 and A6). The lowest area airborne lead concentrations were in the administrative building's conference room, the laundry room, the water treatment plant, and the dirty side of the locker room (Appendix A, Tables A4, A5, and A6).

Wipe Sampling for Lead

We took 57 wipe samples over two visits. The results of these samples should be used as a relative indicator of surface contamination, i.e., a surface with 500 micrograms per 100 square centimeters (µg/100 cm^2) would be considered more contaminated than a surface with 50 µg/100 cm^2, though the results are all considered semi-quantitative. Of the 57 samples, four wipes with the highest lead loadings were outliers: 25,000 µg/100 cm^2 on the clothes dryer exhaust vent; 23,000 µg/100 cm^2 on the sole of an employee's boot after boot washing; and 5,200 µg/100 cm^2 (visit 1) and 730 µg/100 cm^2 (visit 2) on the concrete floor at the doorway in the conference room antechamber leading into the administrative building. Results of the other 53 wipes are shown in Table 2, ranked by area from highest to lowest geometric mean (GM) lead loading.

Table 2. Summary of surface wipe samples for lead, April and September 2012

Area	No. of samples	Concentrations (µg/100 cm^2)	Geometric mean	Geometric standard deviation
Soles of sandals worn by employees in shower area	3	370 to 540	455	1.2
Miscellaneous surfaces (e.g., water fountain, hand punch timeclock)	3	330 to 430	391	1.2
Changing area and dirty locker room	4	63 to 600	317	2.9
Shower room floor	4	100 to 280	200	1.6
Inside surface of respirators after use	3	110 to 330	168	1.8
Laboratory floor	1	92	92	NA
Laundry room surfaces	3	17 to 85	50	2.5
Clean locker room floor and lockers (visit 1)	4	5.5 to 180	47	4.6
Administration building hallway and lobby	12	4.2 to 150	34	3.1
Clean locker room floor and lockers (visit 2)	5	2.6 to 130	16	5.6
Shuttle bus interior surfaces	6	2.9 to 16	7	2.0
Employee lunch room tables and floor	5	0.9 to 46	7	5.4

Results of the hand wipe samples from the first visit returned a GM lead loading of 122 µg (range: 36 to 940 µg/wipe). For the second visit, the GM lead loading on the hands of the employees was 48 µg (range: 23 to 230 µg/wipe). Researchers have found that it is difficult to remove lead on the hands after routine hand washing with soap, no matter how diligently employees wash their skin [Sato and Yano 2006]. This finding suggests that preventing skin contamination should be the primary goal because encouraging better hand hygiene may not be sufficient to reduce skin contamination alone.

There are no OELs for lead on work surfaces, clothing, or skin. The OSHA lead standard states that all work surfaces should be maintained as free as practicable of accumulations of lead [29 CFR 1910.1025].

We detected the highest levels of lead on the laundry dryer exhaust vent (25,000 µg/100 cm^2), suggesting that lead was still present on work uniforms after washing. High lead levels were also found on the sole of an employee's work boot after cleaning (23,000 µg/100 cm^2). This finding suggests that the boot washing process was inadequate and that cross-contamination could occur if employees walked into a clean area wearing contaminated boots. While considerably lower than the level on the sole of the work boot, we detected levels of lead (GM: 455 µg) on the soles of employees' sandals upon entering or exiting the shower room, which could be a source of contamination to the clean locker room.

We saw a decrease in the quantities of surface lead levels along the pathway from the dirty locker room/changing area (GM: 317 µg), to the shower area (200 µg), and finally to the clean locker room (GM of 47 µg on the first visit and 16 µg on the second visit). The continued presence of lead in the clean locker room suggests that employee cleaning practices did not adequately remove lead and prevent the transfer of lead from the dirty to the clean areas. However, the decrease between the first and second visits in the levels of lead found in the clean locker room suggests improved practices.

We measured lead on the lobby and hallway floors and other surfaces of the administration building (GM: 34 µg), suggesting some contamination was occurring in these areas. The lowest surface lead levels we measured were in the employee lunchroom and inside the employee shuttle bus; both had GMs of 7 µg. This was not surprising because we observed a custodian cleaning the lunchroom throughout the workday, and employees were required to shower before entering the lunchroom. Also, the shuttle surfaces appeared to be free of accumulated dust levels, likely as a result of regular cleaning practices implemented during each shift.

The results of our laboratory analysis of eight wipe samples collected by the company closely matched the company's interpretation of the visual color change on these wipes. The company interpreted all eight wipes as having no color change. Laboratory analysis of the eight samples returned a GM lead loading of 9 µg (range: 4.9 to 26 µg; geometric standard deviation: 1.8), below the limit of detection of 20 µg required for a color change indicating the presence of lead with the visual method.

The limit of detection required for a color change for the wipes we used was 18 µg; increasing color intensity suggests a larger quantity of lead loading. We classified the color change of each wipe sample as: (–) indicating no color change and no indication of lead above the limit of detection; (+) indicating less of a color change, suggesting a minimal to smaller quantity of lead; and (++) indicating more of a color change, suggesting a larger quantity of lead on the wipe. Laboratory analysis of the wipes demonstrated that the visual identification of the surface wipe samples in this manner was fairly reliable. Eighteen of 19 surface wipes classified as (–) showed lead loadings at or below 19 µg; the GM lead loading for the 19 samples was 7 µg (range: 0.9 to 35 µg; geometric standard deviation: 2.6). Twenty-one surface wipes classified as (+) returned a GM lead loading of 81 µg (range: 21 to 430 µg; geometric standard deviation: 1.9). Seventeen surface wipes classified as (++) returned a GM lead loading of 709 µg (range: 150–25,000 µg; geometric standard deviation: 4.6). Upon examination of the hand wipe sampling results from both visits, all 15 of the (–) selections were over the lower limit of visual identification, up to as high as 230 µg of lead. The color change of the hand wipe samples did not predict the quantity of lead as reliably as those of the surface wipe samples. One possible reason for this finding is that the D-Lead® soap used by employees contained a chemical called ethylenediaminetetraacetic acid, which binds to lead. Residual lead-ethylenediaminetetraacetic acid complex on the surface of the skin may have collected on the hand wipes. Insufficient lead ions may not have been available to create the necessary chemical reaction for a change in color on the wipes, even though lead was present. Because of these differences, occasional follow-up quantitative analysis of wipes can be beneficial in assessing dermal contamination and the effectiveness of lead removal practices when results of wipes are negative or low.

Noise Exposures and Hearing Conservation

Appendix A, Table A7 shows sound level measurements. The highest sound levels, near the battery breaker when batteries were shredded, ranged from 95–98 decibels, A-scale (dBA). The sound levels were 89–92 dBA at the location where employees loaded batteries onto the conveyor. Sound levels ranged from 94–97 dBA when employees removed slag with a jackhammer and from 92–93 dBA during ingot casting, mainly due to the metal-to-metal contact.

Full-shift TWA personal dosimetry measurements are shown in Appendix A, Table A8. Noise exposures for employees in all job titles we monitored were at or above the NIOSH REL. Personal noise exposures of employees in the battery breaker, foundry, and furnace areas were also at or above the OSHA action level. Employees at the battery breaker conveyor had the highest TWA noise exposures. Although we did not monitor employees casting ingots, on the basis of area sound levels, noise exposures for employees in this area would also likely exceed the NIOSH REL and OSHA action level. Maintenance mechanics' noise exposures were at the REL, but would be higher if their maintenance work occurred in higher noise areas. Overall noise exposures increased as the level of production increased, and noise levels exceeded the OSHA action level for most job titles when full production occurred.

One-third octave band measurements at the battery breaker and lead casting showed that predominant noise frequencies at both areas were 630 hertz to 5,000 hertz. Properly designed acoustic enclosures for the battery breaker and in the casting area could reduce noise levels and may also help control dust and reduce employees' lead exposures. Noise reduction should be part of an overall hearing loss prevention strategy. For example, when equipment is replaced, the amount of noise generated by the new equipment should be considered.

We saw only a few employees wearing hearing protection, although insert-type ear plugs (Radians) were readily available. Some employees who used earplugs did not properly insert them into their ear canal. Poorly inserted or fitting hearing protectors can reduce the ability of the hearing protectors to reduce noise. The company posted the types of PPE required but did not include hearing protection. Given our observations, it is important for the company to emphasize consistent and proper use of hearing protection. Methods for fit testing of hearing protection are available from some manufacturers to help ensure proper selection and fit.

Heat Stress

Heat stress measurements for the furnace and kettle areas are shown in Appendix A, Table A9. The WBGT index inside the work facility was 60°F–88°F during our evaluation. The outdoor daytime high temperatures, as recorded by the National Oceanic and Atmospheric Administration, were approximately 89°F on the days of the evaluation. Average summer high temperatures are typically in the low 90s°F, but can reach to the upper 90s°F. Heat conditions were similar between the kettle and furnace areas except during lead casting when the kettle area became hotter. We estimated that foundry and battery breaker work required a moderate level of effort [ACGIH 2014]. Using the WBGT reading of 88°F (the highest we recorded during our evaluation), and estimating that the majority of employees would fall into the category of moderate work effort, we determined that for conditions similar to those during our evaluation, employees should follow a schedule of 30 minutes of work, followed by 30 minutes of rest [NIOSH 1986]. The company did not have a written heat stress program, and employees did not follow a work and rest schedule during the workday. Cool drinking water was available, and we saw employees taking breaks in the shade and splashing water on their faces during the workday, but the plant did not have air-conditioned recovery areas. Of 26 employees interviewed, 22 reported working in hot conditions. To stay cool most of these employees reported drinking water from the water fountains, finding shade, and frequently splashing water on their face.

Employee Interviews

Participation and Demographics

Employees from all departments, except administration, participated in confidential medical interviews. We interviewed 26 employees in English or Spanish. Three employees declined an interview. The company had 106 employees at the time of our first visit, including managers. Most participants we interviewed were male with an average age of 34 (range: 22–65). Of those we interviewed the average length of employment with the company was 5 years (range: 0.5–10 years).

Safety and Health Concerns

When asked if they had any health concerns or health conditions related to their job, two interviewed employees were concerned that they did not know how lead exposure affected their health and two were uncertain about which specific actions to take to keep their exposure to lead to a minimum. One interviewed employee was concerned about not being able to see the plant physician. According to the plant physician at the time of our evaluation, the plant physician was on-site once a week for 3–5 hours. Three interviewed employees described skin irritation or small burns on their arms from the splatter of molten lead and battery acid. Also, three interviewed employees described joint pain and body aches. One interviewed employee was concerned about handling lead acid batteries, one was concerned about arsenic use in the lab, one was concerned with take-home lead, and one was concerned with bringing lead-contaminated undergarments home to wash.

All interviewed employees were aware of their most recent individual BLL test results. The plant physician recommended that employees with elevated BLLs take a naturopathic (a form of alternative medicine) pill to lower their BLL. Eight of 26 (31%) reported they had been given this naturopathic supplement. Dietary supplements are not regulated by the U.S. Food and Drug Administration or approved for use in treating specific medical conditions. Use of dietary supplements without oversight by a physician who is familiar with a patient's overall medical history may put individuals at risk for developing complications, drug interactions, and possible allergic reactions. In fact, some herbal supplements may contain lead and specific herbal supplements are associated with higher BLLs among women [Buettner et al. 2009].

Employee Symptoms

Of the 26 employees interviewed, 22 (85%) reported within the past 3 months at least one symptom that could be related to lead exposure. Most of these 22 employees worked in the foundry. Thirteen of 26 interviewed employees reported being tired within the past 3 months. Also, within the past 3 months, 10 interviewed employees reported headaches, 10 reported joint pain, and 10 reported unexplained occurrences of waking up. Some interviewed employees reported more than one symptom. These symptoms are listed in Appendix A, Table A10. These symptoms have been associated with elevated BLLs, although these symptoms are not limited to lead exposure. People with chronic lead poisoning may not have symptoms or they may have nonspecific symptoms. More information on acute and chronic health effects of lead is in Appendix B.

Policies and Procedures for Lead

Record Review

We reviewed the medical records for the one employee evaluated for lead intoxication in 2011. The diagnosis was work-related "heavy metal toxicity" based on elevated BLL (32 µg/dL) and zinc protoporphyrin levels (76 µg/dL). This employee's treatment was referred to a government-owned corporation of Puerto Rico that provides workers' compensation.

Seventy-one total entries were reported on the OSHA Logs for 2010–2012. Contusions were the most commonly reported event, accounting for about 42% of all injuries. One incident of lead poisoning was reported by a maintenance employee in 2010, and three incidents were reported by employees working as operators in the grinder area in 2011.

Blood Lead Levels

- BLL results are shown in Appendix A, Table A11. Using contract laboratories, the company tested employees every 6 months from July 2009 to July 2011 before switching to testing every 3 months. The company provided copies of their BLL records and laboratory reports for all employees from July 2009 through July 2013 with the exception of 3 months, where only the company's BLL records were provided. We used the company data only for these 3 months to calculate our results due to the good agreement between the laboratory reports and company reports for the other months. Figure 6 shows a downward trend of BLL from July 2009 to July 2011 among employees in the battery shredding, foundry, maintenance, and manufacturing areas and those employees operating tractors. BLL data for one or more employees in 2009, 2010, 2011, 2012, and/or 2013 were missing because of employment status.
- This decline in employee's BLLs may have resulted from a combination of a heightened focus on lead exposures, hygiene practices, and facility design, requiring more employees to wear respirators, switching to respirators with a higher protection factor, or other workplace changes. However, despite improving the respiratory protection program and reducing average BLLs by 50%, in 2013, 78% of employees had an average blood lead level at or above the recommended limit of 10 µg/dL. A BLL more than 10 µg/dL is considered elevated [Kosnett et al. 2007].

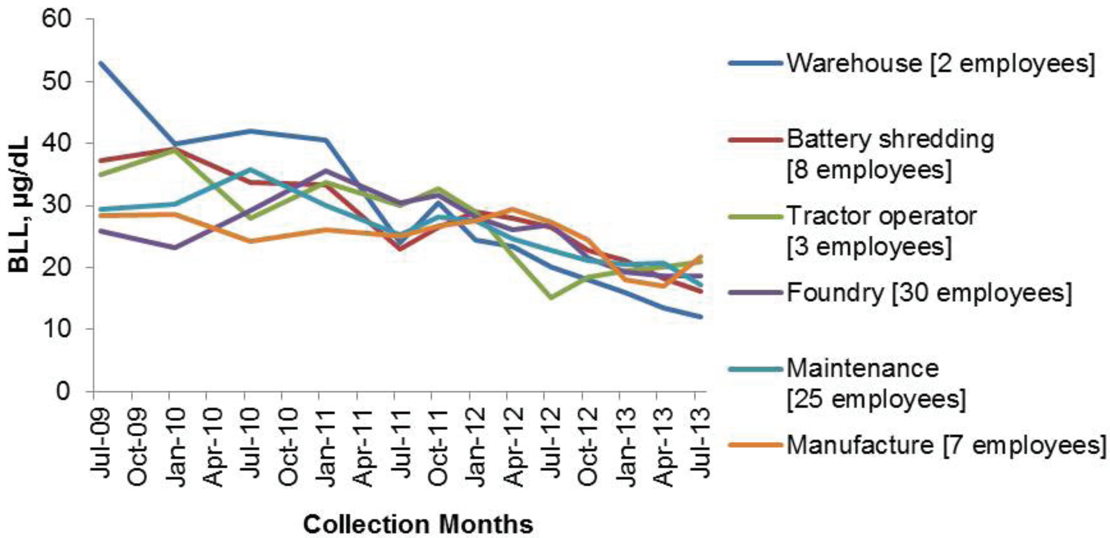

Figure 6. Average BLLs for July 2009–July 2013.

Respiratory Protection

Of 26 interviewed employees, 22 reported wearing a respirator all day. The remaining four employees we interviewed reported not wearing a respirator when driving a truck or outside the lab. All 26 employees reported changing the respirator prefilter daily and the cartridges either every 2 weeks or monthly. Given the high levels of airborne lead identified for specific activities, this cartridge change-out schedule may not be sufficient for all workers. A more formal assessment to determine cartridge change-out is needed. When asked, 25 of 26 interviewed employees reported receiving respirator training, and several reported this training occurred upon hire. In the written respiratory protection program, the company states that "refresh" training was conducted periodically according to legal requirements and needs, or at intervals of at least every 3 years. OSHA requires annual training for employees who wear respirators.

We saw tight-fitting respirators worn incorrectly. As examples, we noted employees having more than 1 day of beard growth wearing respirators. Employees must be clean shaven in the area of the facepiece seal to achieve sufficient protection as required in the OSHA respiratory protection standard. We also saw employees pulling their respirator away from their face to speak in the production areas, which allowed exposure to lead dust. Even brief periods of disuse can result in significant lead exposures. We found two respirators placed near the casting area where they could easily get contaminated with lead dust. As noted earlier, we found lead dust inside cleaned respirators indicating that this contamination was not sufficiently removed between respirator uses. We saw battery breaker employees wearing full facepiece respirators to protect their eyes and face from acid splashes, but they wore no other protective clothing to prevent exposure to their skin.

Hearing Protection Program

The company had a written hearing conservation program that included information on the training and use of hearing protection. The program did not have information about completing employee hearing testing (audiograms) upon hire and annually thereafter, and the company did not provide baseline audiograms for new hires or follow-up audiometric testing for employees as required by the OSHA noise standard.

Locker Rooms, Shower, and Employee Lunchroom

Between our first and second visits, the company changed the locker area by adding a sandal wash station and altering how employees entered the clean locker room and shower areas. However, in September 2012 we saw employees crossing potentially lead-contaminated areas when returning from the shower area to the clean locker room. We also saw employees walking in their socks in the dirty locker room, a practice that would cross-contaminate their personal clothing.

At our second visit, employees used a stationary boot scrub with water jets to clean the soles of their work boots before entering the dirty locker room. This was an improvement over the practice seen during our first visit when employees used a water hose and scrub brush to clean the soles of their work boots. After cleaning their boots, employees removed their work uniforms and deposited them in a laundry chute before entering the dirty locker room. Once in the dirty locker room employees placed their work boots and respirators in individual lockers, put on sandals, and picked up a company-provided clean towel before entering the shower. Because we found lead in the shower area during our first visit, the company required employees to clean their sandals before entering the shower. After showering, employees walked from the shower to the clean locker room where they changed into their street clothes before leaving the plant.

On the basis of recommendations we made during our first visit, the company provided us with a proposed plan outlining where employees would remove their work boots, respirators, and other PPE before entering the dirty locker room, shower, and clean locker room. The proposed plan appeared to eliminate opportunities for cross-contamination for employees coming to work and leaving for home. However, employees could still cross a potentially contaminated path when walking from the clean locker room to the employee lunchroom.

Other Observations

Fall Protection

We saw an employee standing more than 6 feet above a lower level without fall protection using a jackhammer to remove slag from the interior of a kettle. We saw an unsecured and uneven walking surface at the battery breaker that was more than 6 feet above a lower level. OSHA requires a guardrail and toeboard around every open-sided platform, floor, or runway that is 4 feet or higher off the ground or next level [29 CFR 1910.23].

Ventilation

The plant had a dust collection system to capture emissions from the furnaces and kettles. However, there was no local exhaust ventilation at the battery breaker and shredder, and we saw dust emitted from both operations. The highest area air sample results we obtained for lead were taken on a handrail near the battery breaker (1,900 µg/m^3) and on the shredder conveyor (2,500 µg/m^3) (Appendix A, Tables A4 and A6).

Employees mixed dried lead with soda ash and lead scrap using front-end loaders in an open area in the middle of the foundry. Air concentrations of lead in this area (ranging up to 640 µg/m^3, Appendix A, Table A5) were second only to the area air lead levels measured at the battery shredder operations. In addition, the cabs of the front-end loaders were not enclosed. A front-end loader operator was the most highly lead exposed employee (4,100 µg/m^3, Appendix A, Table A1), and all foundry employees had personal exposures exceeding the OSHA PEL and NIOSH REL.

Figure 7. Employee using skid loader with rotary brush attachment to sweep dry floor. Photo by NIOSH.

Employees used a rotary brush attachment on a Bobcat® skid loader to dry sweep the plant floor (Figure 7), creating large dust clouds. We also saw employees dry sweeping the floor with brooms and shoveling and sweeping spilled lead dross. Another lead dust-generating task was removing hardened material from the interior of kettles with a jackhammer. An employee who spent 25 minutes doing this task had a lead exposure of 2,700 µg/m^3.

Although the ingot and kettle area had exhaust ventilation, we noticed several right angle bends in the ductwork above the kettles. The use of sharp angles in ducts is poor ventilation design because it reduces the efficiency of the ventilation system. This problem may partly explain why the third highest personal air sample result from this evaluation (2,700 µg/m^3, Appendix A, Table A1) was collected on an employee who was drossing at the kettles.

During our evaluation we learned that the company was planning to partially or fully enclose the production building to reduce lead releases to the outdoors. The current building design allowed outdoor air to enter. A partial or full enclosure of the building without further ventilation controls will likely increase employee airborne lead concentrations, as well as temperature and relative humidity levels.

Safety Hazards

At the end of each of our visits, we informed the company of the following safety hazards we observed:

- The guard for the belt drive of the shredder was missing (Figure 8).
- The protective insulation on electrical wires for the shredder motor was pulled away, exposing the inner wires (Figure 8).
- The metal battery shredder motor casing was corroded from acid mist (Figure 8).
- The walkway on the battery breaker was uneven and not secured (Figure 9).
- A corner of the guardrail on the battery shredder platform was loose (Figure 10).

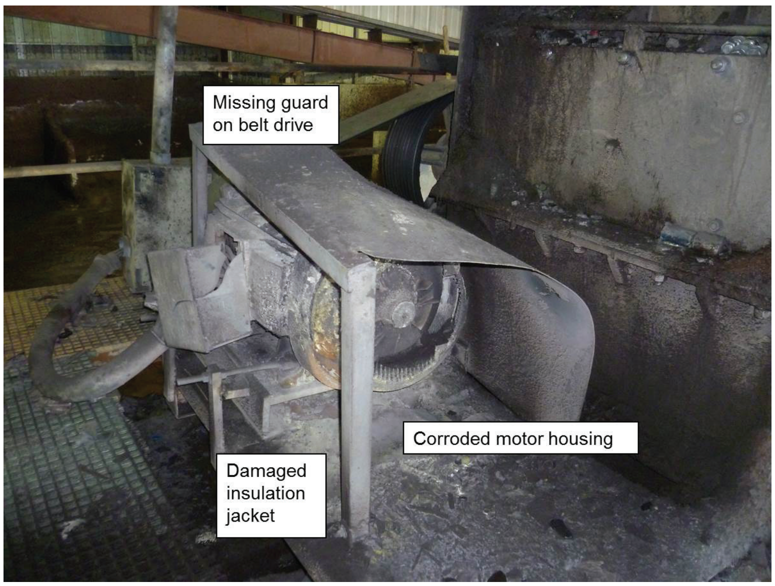

Figure 8. Corroded metal housing surrounding the shredder motor, damaged electrical insulation, and an unguarded drive belt. Photo by NIOSH.

Figure 9. Unsecured and uneven walking surface on battery breaker mezzanine. Photo by NIOSH.

Figure 10. Unsecured guardrail on battery breaker mezzanine. Photo by NIOSH.

We saw electrical hazards in the plant, including electrical cords plugged into damaged outlets, damaged insulation or plugs on electrical cords, missing electrical outlet cover plates, and an open high-voltage electrical panel. An eyewash station located between the main building and the bag house building had poor water flow at the right nozzle. We also saw the following problems during our first visit that we pointed out to plant managers during our closing meeting.

- Employees did not wear seatbelts when operating forklifts and front-end loaders.
- A propane fuel cylinder was not attached securely to a forklift.
- Oxygen and acetylene fuel gas cylinders were stored next to each other, and some compressed gas cylinders did not have valve protection caps or were not secured upright.

Conclusions

All employees except those working in the enclosed control room and in the water treatment area were overexposed to lead. The highest lead exposures were measured on employees loading and unloading furnaces, drossing kettles and castings, and operating the battery breaker and shredder. Some employees had lead exposures exceeding their respirator's protection factor. Eighty-five percent of interviewed employees reported at least one symptom that could be related to lead overexposure. On the basis of company data collected in 2013, 78% of the company's employees had average BLLs at or above 10 µg/dL, a level considered elevated. Ventilation controls to reduce lead dust at the furnaces, casting, and battery breaker performed poorly or were nonexistent. We also found employees overexposed to noise and had potential to be exposed to heat stress conditions. The company did not have a hearing conservation or a heat stress management program. Lack of knowledge about the health effects of lead among some employees and how they could help protect themselves indicates deficiencies in the hazard communication program. The respiratory protection program was deficient because some respirators did not have a protection factor sufficient for the employee's lead exposure, training was not conducted annually, and we saw respirators worn and stored incorrectly by employees.

Recommendations

On the basis of our findings, we recommend the actions listed below. We encourage the lead-acid battery recycling company to use an employee-management health and safety committee or working group to discuss our recommendations and develop an action plan. Those involved in the work can best set priorities and assess the feasibility of our recommendations for the specific situation at the battery recycling company.

Our recommendations are based on an approach known as the hierarchy of controls (Appendix B: Occupational Exposure Limits and Health Effects). This approach groups actions by their likely effectiveness in reducing or removing hazards. In most cases, the preferred approach is to eliminate hazardous materials or processes and install engineering controls to reduce exposure or shield employees. Until such controls are in place, or if they are not effective or feasible, administrative measures and personal protective equipment may be needed.

Elimination and Substitution

Eliminating or substituting hazardous processes or materials reduces hazards and protects employees more effectively than other approaches. Prevention through design, considering elimination or substitution when designing or developing a project, reduces the need for additional controls in the future.

1. Make a path so that employees can go from the clean locker room to the lunchroom without crossing lead-contaminated areas.

Engineering Controls

Engineering controls reduce employees' exposures by removing the hazard from the process or by placing a barrier between the hazard and the employee. Engineering controls protect employees effectively without placing primary responsibility of implementation on the employee.

1. Install ventilated enclosures around the battery breaker and shredder to reduce airborne lead exposures and noise levels.
2. Stop dry sweeping to clean the floors. Use wet cleaning methods or vacuums with high-efficiency particulate air filters.
3. Separate the lead and lead oxide storage areas from the battery breaker area with walls.
4. Perform dust-generating tasks in ventilated enclosures.
5. Use drossing tools with longer handles, and store collected dross in ventilated containers.
6. Remove sharp angles in exhaust ventilation ducts at the kettle and ingot casting areas.
7. Clean lead from equipment before performing maintenance.
8. Repair the guardrail and walking surface on the battery breaker mezzanine.
9. Install a guard on the belt drive of the battery breaker motor. Keep it in place at all times.

10. Provide fall protection, guardrails, or other measures to protect employees working 4 feet or greater off the ground or next level.
11. Consider the possibility of increased airborne lead exposure and heat stress on employees when designing an enclosure for the production building. Use local exhaust ventilation and process enclosures whenever possible to minimize employee lead exposures. Do not rely on respiratory protection alone to control employee exposures.
12. Secure all compressed gas cylinders properly with a metal strap or chain.
13. Store fuel gas cylinders more than 20 feet from oxygen cylinders, unless separated by a noncombustible barrier at least 5 feet high and with a fire resistance rating of 30 minutes.
14. Make sure all cylinders have a valve protection cap that is securely hand-tightened.
15. Make sure all heavy moving equipment have seat belts and that employees use them.
16. Make sure all electrical outlets have cover plates and that electrical panel doors are kept closed. Inspect, repair, or replace damaged electrical cords, plugs, and outlets.

Administrative Controls

The term administrative controls refer to employer-dictated work practices and policies to reduce or prevent hazardous exposures. Their effectiveness depends on employer commitment and employee acceptance. Regular monitoring and reinforcement are necessary to ensure that policies and procedures are followed consistently.

1. Improve hazard communication training to ensure that all employees are knowledgeable about lead, noise, and heat stress hazards at the worksite, how these exposures affect their health, and what protective measures should be used to prevent exposures.
2. Follow the medical surveillance and occupational exposure limits for lead as discussed in Appendix B. These guidelines are also available through the California Department of Public Health at http://www.cdph.ca.gov/programs/olppp/Documents/medgdln.pdf.
3. Use a healthcare provider who is familiar with the current scientific information about hazards of lead exposure, the Cal/OSHA lead and respiratory protection standards, and respirator use. The American College of Occupational and Environmental Medicine provides guidelines about the confidentiality of medical information in the workplace at http://www.acoem.org/Confidentiality_Medical_Information.aspx.
4. Remove employees with a BLL above 20 µg/dL from any lead exposure. Although OSHA requires medical removal with a BLL above 50 µg/dL, this removal level should be lower based on current scientific knowledge about the health effects of lead exposure. Medical removal means having the employee work in an area that does not have lead in it. The employee should retain his or her full pay and benefits rather than filing for workers' compensation.
5. Educate employees about the importance of keeping their hands and exposed skin as clean as possible while at work, and of washing their hands before eating, drinking, and leaving work. Use a lead removal cleaner because washing hands with regular

soap and water is not effective in removing lead (and other toxic metals) from the skin [NIOSH 2014b]. See http://www.cdc.gov/niosh/topics/lead/ for more information on lead removal products.

6. Use a blood lead testing laboratory that meets the OSHA criteria for proficiency testing to be an approved lab. See https://www.osha.gov/SLTC/bloodlead/protocol.html.
7. Do not use naturopathic pills for reducing BLLs. It is not standard medical practice and is not an effective treatment.
8. Encourage employees to talk to their healthcare provider about their lead exposure and about the risk of take-home lead contamination. Ask employees to get BLL tests for family members, the people they live with, and people who often ride in their vehicles.
9. Review OSHA Logs and BLL laboratory reports to identify employees with higher BLLs and jobs that may need additional engineering or administrative controls.
10. Develop a comprehensive hearing conservation program that includes noise monitoring, employee training on noise hazards, correct use of PPE, and baseline and annual audiometric testing. Requirements of the OSHA noise standard [29 CFR 1910.95] are discussed further in Appendix B. If an audiogram indicates a standard threshold shift, refer the employee for a medical evaluation. Audiologists who evaluate employee audiometric tests should be aware of workplace exposures and possible additive, potentiating, or synergistic effects between noise exposures and lead.
11. Fit employees with properly selected hearing protection. Hearing protection manufacturers can assist.
12. Start a heat stress management program that includes employee training on heat stress hazards and first aid procedures, among others. Establish work/rest schedules based on temperature, humidity, and the type of work. Provide medical surveillance, develop an emergency response procedure for heat-related injuries, and encourage employees to take regular breaks and to drink cool water throughout the work shift. For more information on heat stress and heat strain, see Appendix B and http://www.cdc.gov/niosh/topics/heatstress/. An OSHA–NIOSH information sheet on heat illness that can be carried around by managers and employees is available at http://www.cdc.gov/niosh/docs/2011-174/.
13. Create a health and safety committee that includes employer representatives, health and safety personnel (including the plant physician), and employee representatives. This committee should meet routinely to discuss health and safety issues of concern. Guidelines on how to create effective health and safety committees can be found at https://pantherfile.uwm.edu/groups/sa/usa/public/Safety/safcomm.pdf and http://www.nj.gov/health/peosh/documents/jlmhsc.pdf.
14. Establish a formal, written procedure for reporting and addressing health and safety concerns.
15. Encourage employees to leave their work clothes at the plant. Clothing that is brought home, such as undergarments, should be washed separately from other clothes.

Personal Protective Equipment

Personal protective equipment is the least effective means for controlling hazardous exposures. Proper use of PPE requires a comprehensive program and a high level of employee involvement and commitment. The right PPE must be chosen for each hazard. Supporting programs such as training, change-out schedules, and medical assessment are needed. Personal protective equipment should not be the sole method for controlling hazardous exposures. Rather, PPE should be used until effective engineering and administrative controls are in place.

1. Follow the OSHA respiratory protection standard for general industry [29 CFR 1910.134] for a comprehensive respiratory protection program. Information from NIOSH can also help in developing an effective respirator program. See http://www.cdc.gov/niosh/topics/respirators/. A written program should include the following elements:
    a. written operation procedures
    b. appropriate respirator selection
    c. employee training
    d. effective cleaning of respirators
    e. proper storage
    f. routine inspection and repair
    g. exposure surveillance
    h. program review
    i. medical approval
    j. use of approved respirators
2. Ensure all aspects of the OSHA respiratory protection standard are correctly implemented. These include:
    a. ensuring that employees are clean shaven when wearing respirators
    b. using appropriate fit testing procedures for the selected respirators
    c. wearing respirators all the time while in work areas of required respirator use
    d. developing a formal respirator cartridge change-out schedule to determine if current change-out practices are sufficient
3. Require employees loading furnaces and drossing kettles to wear a higher level of respiratory protection than that observed to be used during the NIOSH visits until controls reduce airborne lead concentrations. According to NIOSH respirator selection guidance, employees performing these jobs should wear a pressure-demand supplied-air respirator with a half-mask or a full facepiece. However, OSHA respirator selection guidance considers the tight-fitting full facepiece powered air-purifying respirators currently in use by company employees as protective.
4. Provide mandatory annual respiratory protection training for employees in the respirator program, as defined in the OSHA respiratory protection standard [29 CFR 1910.134]. Observe employees to ensure that they are using and storing their respirators properly.
5. Require hearing protection in all areas of the main plant.

Appendix A: Tables

Table A1. Personal air sample results for lead, September 11, 2012

Job title	Tasks	Time (minutes)	Concentration (µg/m^3)
Foundry	Loading and unloading furnace using forklift	355	4,100
	Drossing	391	2,700
	Loading furnace using forklift	347	900
	Working with pots, kettles, ingots	383	630
	Casting ingots	364	470
	Handling caustic soda, cleaning area	382	360
	Production supervisor	371	200
Battery breaker	Loading batteries on conveyor belt	267	220
Warehouse	Warehouse work	273	190
Maintenance	Furnace mechanic	510	67
	Electrician	388	32
Water treatment	Water treatment work	236	18
NIOSH REL and OSHA PEL			50

Table A2. Personal air sample results for lead, September 12, 2012

Job title	Tasks	Time (minutes)	Concentration (µg/m^3)
Foundry	Loading furnace	404	3,700
	Worked with pots, kettles, ingots	336	530
	Loading furnace, on forklift	395	480
	Loader driver	410	450
	Pots	399	180
	Ingot maker	403	93
Battery breaker	Operator, load batteries on conveyor belt	411	250
	Operator, load batteries on conveyor belt	403	190
Warehouse	Warehouse work	407	12
Maintenance	Mechanic on furnace	419	80
	Electrician in control room	410	20
Water treatment	Water treatment work	406	4.0
NIOSH REL and OSHA PEL			50

Table A3. Personal air sample results for lead, September 13, 2012

Job title	Tasks	Time (minutes)	Concentration (μg/m^3)
Foundry	Loading furnace	403	1,100
	Kettle/pots and battery shredding	411	590
	Loading furnace, on forklift	396	450
	Ingot maker	405	350
	Foundry supervisor	398	300
	Forklift driver and loader/mixer	402	130
Battery breaker	Operator, loads batteries on conveyor	412	320
	Operator, loads batteries on conveyor	343	180
Warehouse	Warehouse work	429	62
Maintenance	Industrial mechanic	397	73
	Electrician in control room	407	30
Water treatment	Water treatment supervisor	417	31
NIOSH REL and OSHA PEL			50

Table A4. Area air sample results for lead, September 11, 2012

Area	Location	Time (minutes)	Concentration (μg/m^3)
Foundry	Furnace charge mixing area	435	330
	Between kettles 1 and 2	448	240
	Next to furnace 1	437	210
	Between kettles 4 and 5	436	180
	Ramp between battery breaker and foundry	446	96
	Between slag of furnace 1 and slag of furnace 2	434	79
	Near furnace 2, on kettle #8	451	21
Battery breaker	On hand rail at top of battery breaker	434	1,900
	Base of battery conveyor belt	432	110
	Below battery breaker	435	62
Maintenance	Maintenance shed	397	68
Dirty locker room	Changing area	329	8.0
Outdoor	Background, north of furnaces	389	4.0
Administrative building	Laundry room	91	3.0
	Conference room	539	1.0
Baghouse	Dust box (changed once or twice per shift)	388	2.0
Water treatment	Water treatment plant	354	(0.33)*

*This concentration was between the minimum detectable concentration of 0.3 μg/m^3, and the maximum detectable concentration of 0.10 μg/m^3, based on a sample volume of 0.741 cubic meters. There is more uncertainty associated with this concentration.

Table A5. Area air sample results for lead, September 12, 2012

Area	Location	Time (minutes)	Concentration (µg/m^3)
Foundry	Near loading/mixing area	488	640
	Battery shredding and furnace charge mixing	474	100
	Between pots on control panel	475	100
	Between slag of furnace 1 and slag of furnace 2	502	96
	Ingot machine, on control panel	500	77
	Casting area near exterior door	502	77
	Near pond close to load/mixing area	467	76
	Between kettles 4 and 5	509	68
	Ingots next to drossing station	489	59
Battery breaker	On battery shredding machine, on balcony	504	550
	Base of battery conveyor belt	540	121
	Pond area near shredding	497	79
Administrative building	Conference room	465	1.0

Table A6. Area air sample results for lead, September 13, 2012

Area	Location	Time (minutes)	Concentration (µg/m^3)
Foundry	Mixing area, across from furnaces	440	430
	Between slag of furnace 1 and slag of furnace 2	428	250
	Near furnace, next to the door	416	190
	On post by ramp	380	170
	Between two kettles/pots, on control panel	428	120
	Between kettles 4 and 5	432	98
Battery breaker	On top of battery shredder conveyor	444	2500
	Battery shredder discharge	445	610
	Pool area near battery shredder	424	360
	Base of battery conveyor belt	442	240
	Below battery shredder	436	180
	By washing station, near battery shredder	437	130
Laundry room	By washer	432	11
Conference room	Background	517	1.0

Table A7. Sound level measurements, September 2012

Location	Sound level (dBA)
Battery shredder, on mezzanine	98
Battery shredder, ground level	95
Loading batteries onto battery shredder conveyor	89–92
Employee jackhammering slag out of container	94–97
Ingot casting	92–93
Removing dross from ingots	85
Bobcat driver sweeping floor with rotary brush attachment	86
Kettle area	82–89
Furnace area	81

Table A8. Summary of full-shift TWA personal noise exposures, September 11–13, 2012

Job title	Number Monitored	Noise exposures, expressed in dBA		
		OSHA AL	OSHA PEL	NIOSH REL
Battery shredder	4	78–89	76–86	83–92
Forklift driver and loading/mixing	1	81	76	86
Foundry – drossing	1	85	77	87
Foundry – kettle pots	2	79–85	72–79	84–87
Foundry – oven loader	3	83–87	79–84	87–90
Furnace forklift	2	85–86	80–82	88–89
Maintenance – mechanic	2	76–82	69–73	82–85
8-hour TWA noise exposure limit		85	90	85

Table A9. Heat stress measurement results

Location	Date	Time (military)	Environmental measures			
			Dry bulb (°F)	Globe (°F)	Humidity (%)	WBGT (°F)
Furnace	9/11/2012	0806 – 1555	67–93	69–95	40–96	60–84
	9/12/2012	0732 – 1537	81–94	82–98	46–79	77–86
	9/13/2012	0814 – 1513	83–91	84–94	58–79	79–85
Kettle	9/11/2012	0806 – 1548	68–93	70–98	40–94	62–86
	9/12/2012	0725 – 1531	78–93	81–97	52–85	77–85
	9/13/2012	0804 – 1455	82–97	86–101	53–72	79–88

Table A10. Symptoms reported by interviewed employees* (n = 26)

Symptoms	Number
Being tired	13
Headaches	10
Joint pain	10
Unexplained occurrences of waking up	10
Numbness or tingling of hands or feet	9
Feeling nervous	7
Feeling sad	6
Feeling irritable	6
Problems concentrating	4
Nightmares or strange dreams	3
Loss of appetite	3
Abdominal pains	3
Unexplained weight loss	2
Dizziness	2
Decrease in sex drive	2

*Symptoms reported in previous 3 months.

Note: Some employees reported more than one symptom.

Table A11. Employees' average BLLs, July 2009–July 2013*

Average BLLs	Work areas or work tasks
< 10 µg/dL	Lab
10–19 µg/dL	Administration Health/Safety Truck driver
≥ 20 µg/dL	Warehouse Battery shredding Tractor operator Foundry Maintenance Manufacture Water treatment Laundry

*Based on BLL data obtained from the company; missing blood lead level data for one or more employees in 2009, 2010, 2011, 2012, and/or 2013 because of employment status.

Appendix B: Occupational Exposure Limits and Health Effects

NIOSH investigators refer to mandatory (legally enforceable) and recommended OELs for chemical, physical, and biological agents when evaluating workplace hazards. OELs have been developed by federal agencies and safety and health organizations to prevent adverse health effects from workplace exposures. Generally, OELs suggest levels of exposure that most employees may be exposed to for up to 10 hours per day, 40 hours per week, for a working lifetime, without experiencing adverse health effects. However, not all employees will be protected if their exposures are maintained below these levels. Some may have adverse health effects because of individual susceptibility, a pre-existing medical condition, or a hypersensitivity (allergy). In addition, some hazardous substances act in combination with other exposures, with the general environment, or with medications or personal habits of the employee to produce adverse health effects. Most OELs address airborne exposures, but some substances can be absorbed directly through the skin and mucous membranes.

Most OELs are expressed as a TWA exposure. A TWA refers to the average exposure during a normal 8- to 10-hour workday. Some chemical substances and physical agents have recommended short-term exposure limit or ceiling values. Unless otherwise noted, the short-term exposure limit is a 15-minute TWA exposure. It should not be exceeded at any time during a workday. The ceiling limit should not be exceeded at any time.

In the United States, OELs have been established by federal agencies, professional organizations, state and local governments, and other entities. Some OELs are legally enforceable limits; others are recommendations.

- The U.S. Department of Labor OSHA PELs (29 CFR 1910 [general industry]; 29 CFR 1926 [construction industry]; and 29 CFR 1917 [maritime industry]) are legal limits. These limits are enforceable in workplaces covered under the Occupational Safety and Health Act of 1970.
- NIOSH RELs are recommendations based on a critical review of the scientific and technical information and the adequacy of methods to identify and control the hazard. NIOSH RELs are published in the *NIOSH Pocket Guide to Chemical Hazards* [NIOSH 2010]. NIOSH also recommends risk management practices (e.g., engineering controls, safe work practices, employee education/training, personal protective equipment, and exposure and medical monitoring) to minimize the risk of exposure and adverse health effects.
- Other OELs commonly used and cited in the United States include the TLVs, which are recommended by ACGIH, a professional organization, and the workplace environmental exposure levels, which are recommended by the American Industrial Hygiene Association, another professional organization. The TLVs and workplace environmental exposure levels are developed by committee members of these associations from a review of the published, peer-reviewed literature. These OELs are not consensus standards. TLVs are considered voluntary exposure guidelines for use by industrial hygienists and others trained in this discipline "to assist in the control of

health hazards" [ACGIH 2014]. Workplace environmental exposure levels have been established for some chemicals "when no other legal or authoritative limits exist" [AIHA 2014].

Outside the United States, OELs have been established by various agencies and organizations and include legal and recommended limits. The Institut für Arbeitsschutz der Deutschen Gesetzlichen Unfallversicherung (Institute for Occupational Safety and Health of the German Social Accident Insurance) maintains a database of international OELs from European Union member states, Canada (Québec), Japan, Switzerland, and the United States. The database, available at http://www.dguv.de/ifa/Gefahrstoffdatenbanken/GESTIS-Internationale-Grenzwerte-für-chemische-Substanzen-limit-values-for-chemical-agents/index-2.jsp, contains international limits for more than 1,500 hazardous substances and is updated periodically.

OSHA requires an employer to furnish employees a place of employment free from recognized hazards that cause or are likely to cause death or serious physical harm [Occupational Safety and Health Act of 1970 (Public Law 91–596, sec. 5(a)(1))]. This is true in the absence of a specific OEL. It also is important to keep in mind that OELs may not reflect current health-based information.

When multiple OELs exist for a substance or agent, NIOSH investigators generally encourage employers to use the lowest OEL when making risk assessment and risk management decisions. NIOSH investigators also encourage use of the hierarchy of controls approach to eliminate or minimize workplace hazards. This includes, in order of preference, the use of (1) substitution or elimination of the hazardous agent, (2) engineering controls (e.g., local exhaust ventilation, process enclosure, dilution ventilation), (3) administrative controls (e.g., limiting time of exposure, employee training, work practice changes, medical surveillance), and (4) personal protective equipment (e.g., respiratory protection, gloves, eye protection, hearing protection). Control banding, a qualitative risk assessment and risk management tool, is a complementary approach to protecting employee health. Control banding focuses on how broad categories of risk should be managed. Information on control banding is available at http://www.cdc.gov/niosh/topics/ctrlbanding/. This approach can be applied in situations where OELs have not been established or can be used to supplement existing OELs.

Lead

Inorganic lead is a naturally occurring, soft metal that has been mined and used in industry since ancient times. It comes in many forms (e.g., lead acetate, lead chloride, lead chromate, lead nitrate, lead oxide, lead phosphate, and lead sulfate). Lead is considered toxic to all organ systems and serves no useful purpose in the body.

Occupational exposure to inorganic lead occurs via inhalation of lead-containing dust and fume and ingestion of lead particles from contact with lead-contaminated surfaces. Exposure may also occur through transfer of lead to the mouth from contaminated hands or cigarettes when careful attention to hygiene, particularly hand washing, is not practiced. In addition to the inhalation and ingestion routes of exposure, lead can be absorbed through the skin, particularly through damaged skin [Stauber et al. 1994; Sun et al. 2002; Filon et al. 2006].

Workplace settings with exposure to lead and lead compounds include smelting and refining, scrap metal recovery, automobile radiator repair, construction and demolition (including abrasive blasting), and firing ranges. Occupational exposures also occur among workers who apply or remove lead-based paint and among welders who burn or torch-cut metal structures.

Blood Lead Levels

In most cases, an individual's BLL is a good indication of recent exposure to lead because the half-life of lead (the time interval it takes for the quantity in the body to be reduced by half its initial value) is 1–2 months [Lauwerys and Hoet 2001; Moline and Landrigan 2005; CDC 2013a]. Most lead in the body is stored in the bones, with a half-life of years to decades. Measuring bone lead, however, is primarily done only for research. Elevated zinc protoporphyrin levels have also been used as an indicator of chronic lead intoxication; however, other factors, such as iron deficiency, can cause an elevated zinc protoporphyrin level, so monitoring the BLL over time is more specific for evaluating chronic occupational lead exposure.

BLLs in adults in the United States have declined consistently over time. In the last 10 years alone, the geometric mean BLL went from 1.75 µg/dL to 1.23 µg/dL [CDC 2013b]. The NIOSH Adult Blood Lead Epidemiology and Surveillance System uses a surveillance case definition for an elevated BLL in adults of 10 µg/dL of blood or higher [CDC 2012a]. Very high BLLs are defined as BLLs ≥ 40 µg/dL. From 2002–2011, occupational exposures accounted for 91% of adults with very high BLLs (where exposure source was known) [CDC 2014]. This underscores the need to increase efforts to prevent lead exposures in the workplace.

Occupational Exposure Limits

In the United States, employers in general industry are required by law to follow the OSHA lead standard [29 CFR 1910.1025]. This 1978 standard has not yet been updated to reflect the current scientific knowledge regarding the health effects of lead exposure.

Under this standard, the PEL for airborne exposure to lead is 50 µg/m^3 of air for an 8-hour TWA. The standard requires lowering the PEL for shifts that exceed 8 hours, medical monitoring for employees exposed to airborne lead at or above the action level of 30 µg/m^3 (8-hour TWA), medical removal of employees whose average BLL is 50 µg/dL or greater, and economic protection for medically removed workers. Medically removed workers cannot return to jobs involving lead exposure until their BLL is below 40 µg/dL.

In the United States, other guidelines for lead exposure that are not legally enforceable also exist. Similar to the OSHA lead standard, these guidelines were set years ago and have not yet been updated to reflect current scientific knowledge. NIOSH has an REL for lead of 50 µg/m^3 averaged over an 8-hour work shift [NIOSH 2010]. ACGIH has a TLV for lead of 50 µg/m^3 (8-hour TWA), with worker BLLs to be controlled to, or below, 30 µg/dL. The ACGIH designates lead as an animal carcinogen [ACGIH 2014]. In 2013, the California Department of Public Health recommended that Cal/OSHA lower the PEL for lead to

0.5 to 2.1 µg/m^3 (8-hour TWA) to keep BLLs below the range of 5 to 10 µg/dL [Billingsley 2013].

Neither NIOSH nor OSHA has established surface contamination limits for lead in the workplace. The U.S. Environmental Protection Agency and Housing and Urban Development limit lead on surfaces in public buildings and child-occupied housing to less than 40 micrograms of lead per square foot [EPA 1998; HUD 2012]. OSHA requires in its substance-specific standard for lead that all surfaces be maintained as free as practicable of accumulations of lead [29 CFR 1910.1025(h)(1)]. An employer with workplace exposures to lead must implement regular and effective cleaning of surfaces in areas such as change areas, storage facilities, and lunchroom or eating areas to ensure they are as free as practicable from lead contamination.

Health Effects

The PEL, REL, and TLV may prevent overt symptoms of lead poisoning, but do not protect workers from lead's contributions to conditions such as hypertension, renal dysfunction, reproductive, and cognitive effects [Schwartz and Hu 2007; Schwartz and Stewart 2007; Brown-Williams et al. 2009; IOM 2012]. Generally, acute lead poisoning with symptoms has been documented in persons having BLLs above 70 µg/dL. These BLLs are rare today in the United States, largely as a result of workplace controls put in place to comply with current OELs. When present, acute lead poisoning can cause myriad adverse health effects including abdominal pain, hemolytic anemia, and neuropathy. Lead poisoning has, in very rare cases, progressed to encephalopathy and coma [Moline and Landrigan 2005].

People with chronic lead poisoning, which is more likely at current occupational exposure levels, may not have symptoms or they may have nonspecific symptoms that may not be recognized as being associated with lead exposure. These symptoms include headache, joint and muscle aches, weakness, fatigue, irritability, depression, constipation, anorexia, and abdominal discomfort [Moline and Landrigan 2005].

The National Toxicology Program (NTP) recently released a monograph on the health effects of low-level lead exposure [NTP 2012]. For adults, the NTP concluded the following about the evidence regarding health effects of lead (Table B1).

Table B1. Evidence regarding health effects of lead in adults

Health area	NTP conclusion	Principal health effects	Blood lead evidence
Neurological	Sufficient	Increased incidence of essential tremor	Yes, < 10 µg/dL
	Limited	Psychiatric effects, decreased hearing, decreased cognitive function, increased incidence of amyotrophic lateral sclerosis	Yes, < 10 µg/dL
	Limited	Increased incidence of essential tremor	Yes, < 5 µg/dL
Immune	Inadequate		Unclear
Cardiovascular	Sufficient	Increased blood pressure and increased risk of hypertension	Yes, < 10 µg/dL
	Limited	Increased cardiovascular-related mortality and electrocardiography abnormalities	Yes, < 10 µg/dL
Renal	Sufficient	Decreased glomerular filtration rate	Yes, < 5 µg/dL
Reproductive	Sufficient	Women: reduced fetal growth	Yes, < 5 µg/dL
	Sufficient	Men: adverse changes in sperm parameters and increased time to pregnancy	Yes, ≥ 15–20 µg/dL
	Limited	Women: increase in spontaneous abortion and preterm birth	Yes, < 10 µg/dL
	Limited	Men: decreased fertility	Yes, ≥ 10 µg/dL
	Limited	Men: spontaneous abortion in partner	Yes, ≥ 31 µg/dL
	Inadequate	Women and men: stillbirth, endocrine effects, birth defects	Unclear

Various organizations have assessed the relationship between lead exposure and cancer. According to the Agency for Toxic Substances and Disease Registry [ATSDR 2007] and the National Toxicology Program [NTP 2011], inorganic lead compounds are reasonably anticipated to cause cancer in humans. The International Agency for Research on Cancer classifies inorganic lead as probably carcinogenic to humans [WHO 2006]. According to the American Cancer Society [ACS 2014], some studies show a relationship between lead exposure and lung cancer, but these results might be affected by exposure to cigarette smoking and arsenic. Some studies show a relationship between lead and stomach cancer, and these findings are less likely to be affected by the other exposures. The results of studies looking at other cancers, including brain, kidney, bladder, colon, and rectum, are mixed.

Medical Management

To prevent acute and chronic health effects, a panel of experts published guidelines for the management of adult lead exposure [Kosnett et al. 2007]. The complete guidelines are available at http://www.cdph.ca.gov/programs/olppp/Documents/medmanagement.pdf. The panel recommended BLL testing for all lead-exposed employees, regardless of the airborne lead concentration. The panel's recommendations are outlined in Table B2. These recommendations do not apply to pregnant women, who should avoid BLLs > 5 µg/dL. Removal from lead exposure should be considered if control measures over an extended period do not decrease BLLs to < 10 µg/dL or an employee has a medical condition that would increase the risk of adverse health effects from lead exposure. These guidelines are endorsed by the Council of State and Territorial Epidemiologists [CSTE 2014] and the

American College of Occupational and Environmental Medicine [ACOEM 2010]. The California Department of Public Health recommended keeping BLLs below 5 to 10 µg/dL in 2013 [Billingsley 2013].

Table B2. Health-based medical surveillance recommendations for lead-exposed employees

Exposure category	Recommendations
All lead exposed workers	• Baseline or preplacement medical history and physical examination, baseline BLL, and serum creatinine.
BLL < 10 µg/dL	• Monitor BLL monthly for first 3 months after placement, or upon change in task to higher exposure, then monitor BLL every 6 months. • If BLL increases ≥ 5 µg/dL, evaluate exposure and protective measures, and increase monitoring if indicated.
BLL 10–19 µg/dL	• As above for BLL < 10 µg/dL, plus: monitor BLL every 3 months; evaluate exposure, engineering controls, and work practices; consider removal. • Revert to BLL every 6 months after three BLLs < 10 µg/dL.
BLL ≥ 20 µg/dL	• Remove from exposure if repeat BLL measured in 4 weeks remains ≥ 20 µg/dL, or if first BLL is ≥ 30 µg/dL. • Monthly BLL testing • Consider return to work after two BLLs < 15 µg/dL a month apart, then monitor as above.

Adapted from Kosnett et al. 2007

Take-home Contamination

Occupational exposures to lead can result in exposures to household members, including children, from take-home contamination. Take-home contamination occurs when lead dust is transferred from the workplace on employees' skin, clothing, shoes, and other personal items to their vehicle and home [CDC 2009, 2012b].

The Centers for Disease Control and Prevention considers a BLL in children of 5 µg/dL or higher as a reference level above which public health actions should be initiated and states that no safe BLL in children has been identified [CDC 2013a].

The U.S. Congress passed the Workers' Family Protection Act in 1992 (29 U.S.C. 671a). The Act required NIOSH to study take-home contamination from workplace chemicals and substances, including lead. NIOSH found that take-home exposure is a widespread problem [NIOSH 1995]. Workplace measures effective in preventing take-home exposures were (1) reducing exposure in the workplace, (2) changing clothes before going home and leaving soiled clothing at work for laundering, (3) storing street clothes in areas separate from work clothes, (4) showering before leaving work, and (5) prohibiting removal of toxic substances or contaminated items from the workplace. NIOSH noted that preventing take-home exposure is critical because decontaminating homes and vehicles is not always effective. Normal house cleaning and laundry methods are inadequate, and decontamination can expose the people doing the cleaning and laundry.

Noise

Health Effects

Noise-induced hearing loss is an irreversible, sensorineural condition that progresses with exposure. Although hearing ability declines with age (presbycusis), noise exposure produces more hearing loss than that resulting from aging alone. This noise-induced hearing loss is caused by damage to nerve cells of the inner ear (cochlea) and, unlike some conductive hearing disorders, cannot be treated medically [Berger et al. 2003]. In most cases, noise-induced hearing happens slowly and occurs without notice. Hearing loss is often severe enough to permanently affect a person's ability to hear and understand speech.

Occupational ototoxins (like lead) are chemicals that can cause hearing damage alone or in combination with noise when absorbed into the body [Hwang et al. 2009]. Low-level chronic lead exposure may be an important risk factor for age-related hearing loss, and reduction of lead exposure can help prevent or delay development of age-related hearing loss [Park et al. 2010].

Occupational Exposure Limits

The dBA is a unit for measuring sound levels to assess employee noise exposures. The dBA noise scale is similar to how human ears hear sound frequencies. Because the dBA scale is logarithmic, small increases can represent a large increase in sound energy.

The OSHA noise standard [29 CFR 1910.95] specifies a PEL of 90 dBA as an 8-hour TWA. The OSHA PEL is calculated using a 5 dB exchange rate. This means that for every 5 dB increase in noise levels, you reduce the permitted exposure time by half. You can also express an employee's daily noise dose as a percentage, and a dose over 100% exceeds the OSHA PEL. When noise exposures exceed the PEL of 90 dBA, OSHA requires that employees wear hearing protection and that an employer implement feasible engineering or administrative controls to reduce noise exposures. The OSHA noise standard also requires an employer to implement a hearing conservation program when 8-hour TWA noise exposures exceed the action level of 85 dBA. The program must include noise monitoring, employee notification, observation, audiometric testing, hearing protectors, training, and record keeping. More details on the OSHA noise standard can be found at https://www.osha.gov/dts/osta/otm/noise/standards_more.html.

Audiometric (Hearing) Testing

Hearing test must be conducted in very quiet locations. OSHA requires hearing thresholds to be measured at test frequencies of 500, 1,000, 2,000, 3,000, 4,000, and 6,000 hertz. Individual employee's annual audiograms (hearing tests) are compared to their baseline audiogram to see if a standard threshold shift has occurred. OSHA states that a standard threshold shift has occurred if the average threshold values at 2,000, 3,000, and 4,000 Hz have increased by 10 dB or more in either ear when comparing the annual audiogram to the baseline audiogram [29 CFR 1910.95]. The NIOSH-recommended hearing threshold shift criterion is a 15-dB shift at any frequency in either ear from 500–6,000 hertz measured twice in succession [NIOSH 1998]. Both OSHA and NIOSH hearing threshold shift criteria require at least two audiometric tests. More information on audiometric testing can be found at http://www.cdc.gov/niosh/topics/noise/hearingchecklist.html.

Heat Stress

NIOSH defines heat stress exposure as the sum of the heat generated in the body (called metabolic heat) plus the heat gained from the environment (environmental heat), minus the heat lost from the body, primarily through evaporation. Many bodily responses to heat stress are beneficial because they help regulate internal temperature and help the body adapt (acclimatize) to the work environment. However, at some stage of heat stress, the body's regulatory ability cannot maintain internal body temperature at the level required for normal functioning. As a result, the risk of heat-induced illnesses, disorders, and accidents increases [NIOSH 1986].

NIOSH recommends controlling total heat exposure so that unprotected healthy employees are not exposed to metabolic and environmental heat that exceeds NIOSH criteria. These criteria, based on metabolic and environmental heat combinations, recommend work and rest schedules and other actions that employees can follow to minimize their risk of incurring acute adverse health effects [NIOSH 1986]. More information on heat stress and strain can be found at http://www.cdc.gov/niosh/topics/heatstress/.

The ACGIH heat stress guidelines are similar to NIOSH and consider the body's ability to cool itself and, like the NIOSH criteria, can be used to develop work/rest schedules [ACGIH 2014]. The ACGIH guidelines were developed for a traditional work uniform of long-sleeved shirt and pants, and represent conditions under which it is believed that nearly all adequately hydrated, unmedicated, healthy employees may be repeatedly exposed without adverse health effects [ACGIH 2014]. Although accidents and injuries can increase with increasing levels of heat stress, it is important to note that the TLVs are not directed toward controlling these [ACGIH 2014].

NIOSH and ACGIH criteria can only be used when WBGT data for the immediate work area are available, and cannot be used if employees wear encapsulating suits or garments that are impermeable or highly resistant to water vapor or air movement. Further assumptions include an 8-hour work day, 5-day work week, two 15-minute breaks, and a 30-minute lunch, with rest area temperatures no greater than those in work areas, and at least some air movement. While NIOSH and ACGIH guidelines distinguish between safe and dangerous levels, professional judgment must be used in administering a heat stress management program.

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